A.2.16 Astrobiology Science and Technology for Exploring Planets

1. Scope of Program

1.1 Introduction

A new era of planetary surface exploration has begun that is now at the threshold of determining whether life exists or has existed beyond Earth that requires the development of biologically relevant instrumentation and the capability for extensive, autonomous operations on planetary surfaces. This new phase of planetary exploration, characterized by substantial, sustained presence on the surface of the planets (Mars first, then throughout the solar system), requires the development of new operations and technology toolkits. To this end, in collaboration with the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA), NASA is initiating this Astrobiology Science and Technology for Exploring Planets (ASTEP) program to solicit proposals for investigations that will explore the extreme environments on Earth to develop a sound technical and scientific basis to search for life on other planets.

The ASTEP program is a science-driven exploration program that is expected to result in new science and operational/technological capabilities that enable the next generation of planetary exploration. A unique feature that is central to the ASTEP program is the use of field campaigns to further science and technology. Therefore, proposals that combine the following three concerted thrusts will be given priority:

1) Science: Within this thrust, ASTEP will support science investigations designed to further biological research in terrestrial environments analogous to those found on other planets, past or present. Such investigations should increase our understanding of the limits and constraints (or lack thereof) of life in extreme environments and, therefore, lead to a better understanding of how to seek, identify, and characterize life that may exist or have existed on other planets.
2) Technology: The development of technologies that enable remote searches for, and identification of, life in extreme environments (including planetary surfaces) will be supported by ASTEP. This thrust includes, but is not limited to, astrobiology sensors and instruments, *in situ* laboratories, sample acquisition and handling techniques, remote sample manipulation, mobile science systems (including planetary rovers), techniques for autonomous operations, and self-contained deployment systems.
3) Field Campaigns: This thrust of ASTEP will support systems-level field campaigns designed to demonstrate and validate the science and technology in extreme environments. It is expected that such field test campaigns will be conducted with complete systems in a manner designed to approximate the operations of the system in an actual planetary mission in order to understand the performance, capabilities, and efficiencies associated with the tested systems, as well as gather a set of "lessons learned" during both development and implementation of the field test.

ASTEP is expected to lower the risks of planetary exploration through significant technology development and systems-level field tests in Earth's extreme environments. These tests and campaigns will develop mature appropriate technologies through integration and field testing while obtaining scientific data and operational experience for Astrobiology. The high visibility missions to extreme environments should also provide significant opportunities for student involvement in exploration from scientific discovery to real-time control, inspiring a technologically competent next generation of scientists, engineers, and citizens. Therefore, proposals to ASTEP that provide for student involvement (both graduate as well as undergraduate) are encouraged.

1.2 Program Guidelines and Constraints

Astrobiology is the study of life in the Universe whose goals and objectives are detailed in the Astrobiology Roadmap (see http://astrobiology.arc.nasa.gov/), and the Office of Space Science has planned and is planning missions to Mars and to other planetary bodies of Astrobiology interest (see http://spacescience.nasa.gov/).

To take advantage of the wide range of mission opportunities, NASA requires the development of innovative technologies. Because of limited spacecraft accommodations, scientific instruments must be very small and robust and have low power and telemetry bandwidth requirements. Spacecraft instruments need to operate autonomously or allow supervised teleoperation while conducting complex *in situ* sample analyses. Successful instruments will have to operate in environments characterized by extremes of temperatures, pressures, gravity, high-g landing impacts, vibration, and/or high radiation. Sensors already exist that range from fingernail to matchbook sizes, and a wide array of miniaturized chemical laboratories exist that can fit on a compact disk. However, relatively few such developments are as of yet ready to be successfully proposed for space flight to address Astrobiology objectives.

In addition to operating in extreme environments, these sensor and instrument systems will need to be deployed to multiple locations within the investigation site, thereby requiring the integration of suites of instruments with mobility and manipulation systems that are capable of locating and then traveling to sites of interest, placing the instruments in contact with precisely identified targets, and/or acquiring samples and placing them in contact with the instrument sensors. It is anticipated that the mobility systems will also provide infrastructure support for the instrument suites (e.g., communications, computation, structural support, thermal control, power, etc.).

It is intended that the products of the ASTEP Program will be initially utilized by the space flight projects planned for the NASA Mars Exploration Program (MEP) (http://mars.jpl.nasa.gov/) and the NASA Solar System Exploration Program (http://sse.jpl.nasa.gov/).

Technology development and field test campaign proposals in all areas relevant to astrobiology and planetary exploration goals and objectives will be considered for the ASTEP program. However, the program recognizes a particular need for proposals for technology maturation, science data collection, and operations analysis in the following areas:

- Instrument suites for *in situ* identification and analysis of biomarkers;
- Long-term characterization of life-supporting environments;
- Integration of science instrument suites with mobile platforms (rovers);
- Autonomous instrument deployment and placement;
- Autonomous recognition of unexpected science phenomena;
- Self-contained mobile science systems;
- Mobile science platforms; and
- Subsurface sample acquisition systems.

Several science and technology development programs have produced component technologies, capabilities, and resources that may be of utility in constructing complete systems for field test campaigns or further technology development. Utilization and leveraging of these component technologies and/or subsystems is permitted and encouraged. References and further information on these representative technologies can be found on the World Wide Web at http://ranier.hq.nasa.gov/ASTEP/astep.html.

1.3 Campaigns for Field Tests

Field campaigns for the testing of technologies relevant to this ASTEP program may be proposed and may cover a wide range of environments that are analogous to different past or present planetary environments. Examples of field test campaigns are given below to demonstrate the breadth, applicability, and excitement of this approach (Note: these examples are only representative of possible campaigns and do not represent either explicitly or exclusively a list of possibilities). Finally, note that while proposals for field test campaigns are encouraged in response to this solicitation, it is incumbent on the proposer to demonstrate that access to the site proposed for the operation of experiment apparatus is in fact tenable both physically and, for those locales not under the control of the U.S., politically, and appropriate budget resources are allocated for the operations.

Remote Explorer

Ground-based systems can provide platforms for detailed local investigations of regions identified as likely candidate locations for the detection of life signs. For example, such a project might utilize a Mars-analog environment to validate remote science operations and technologies for Astrobiology missions that focus on long duration and autonomous operations by combining an existing mobile robotic platform with a representative suite of astrobiology instruments, deploying the system in a remote location (for example, polar regions), and operating the system from the continental U.S. through a telecommunications link consistent with those used for communications with NASA's planetary missions.

Volcanic Firewalker

Ancient and active volcanoes exist throughout the solar system and may have provided key ingredients for life-supporting environments (energy, chemistry, and possibly liquid water) and, therefore, are high priority targets for searches for evidence of life. Thus, the deployment of a robotic exploration system to search and analyze the interior of volcanic craters, including fumaroles, to identify potential habitats for life could validate science operations and technologies for exploring similar features on other planets.

Ice Penetrator

Sub-ice oceans on Europa may harbor life-supporting environments. Methods and technologies for accessing and exploring environments beneath deep ice-cover are not well understood, they could be tested in the Earth's own polar regions. This system could utilize sub-ice environments as Europa analogs to develop strategies to access and explore the sub-surface. Such efforts would focus on the technical difficulties of ice penetration, of planetary protection through the use of non-contaminating sampling techniques, of the potential for environmental degradation, of communication and exploration systems, and of the challenges of biomarker identification in extremely low-energy environments.

Hydrothermal Vent Monitor

Using the terrestrial sub-sea environment as an analog for Europa, or other early planetary environments, a campaign to conduct long-term examinations of deep-sea volcanic vents, as well as more violent eruptions that could even bring life forms from far beneath the sea floor to the surface, would be relevant to the ASTEP program. Deep-sea exploration platforms ("aqua-bots") exist, but require considerable surface infrastructure that is not tenable for a space flight mission. However, it might be possible to modify such a system for stand-alone operation in support of biology science packages. Such a campaign might conduct operations with only minimal intervention for many months or even years, therefore, requiring the development of systems having a significant degree of autonomy.

2. Programmatic Information

2.1 Guidance for Field Test Campaigns

This is a joint announcement that will enable a single proposal to serve as a vehicle for research support that might include access to extreme polar and/or under-sea environments. Interagency collaboration in this solicitation recognizes the broad interest in the value of exploring extreme environments while simultaneously developing robotic capabilities that may be of value to NASA's planetary exploration program.

The NSF funds and manages the U.S. Antarctic Program (USAP), which carries forward the Nation's goal of supporting the Antarctic Treaty, fostering cooperative research with other nations and protecting the Antarctic environment, among other activities. Research is supported in Antarctica that can only be done, or can best be done there. For research that requires access to Antarctica, information concerning logistical support may be obtained from:

Dr. Polly Penhale
Biology and Medicine Program
Office of Polar Programs
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Telephone: (703) 292-1033
E-mail: penhale@nsf.gov.

Additional information is available in publication NSF 01-81, available at http://www.nsf.gov/cgi-bin/getpub?nsf0181. Note that planning for Antarctic fieldwork must begin at least 18 months in advance of field deployment and must include an analysis of the environmental impact of the proposed project. In addition, programs proposed for work in Antarctica must be consistent with international planning efforts undertaken in cooperation with Antarctic Treaty nations, where applicable.

For projects proposing work in the Arctic, logistics support information may be available from the NSF Arctic Research Support and Logistics program through

Dr. Simon Stephenson
Arctic Research Support and Logistics
Office of Polar Programs
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Telephone: (703) 292-7435
E-mail: sstephen@nsf.gov.

Additional information for fieldwork activities are available at http://www.vecopolar.com/.

Proposers requiring the use of a University-National Oceanographic Laboratory System (UNOLS) ship or submersible, or the U.S. Coast Guard (USCG) icebreaker in the Arctic, must submit a ship request form to NSF's Division of Ocean Sciences as well as the UNOLS office and the operator of any requested ship or ships. For further information, contact:

Dr. H. Lawrence Clark
Head, Ocean Section
Division of Ocean Sciences
4201 Wilson Boulevard.
Arlington, VA 22230
Telephone: (703) 292-8580
E-mail: hclark@nsf.gov.

Ship request forms are available electronically on the UNOLS site at http://www.unols.org/scheduling.html. Printed copies of the form may be obtained from the UNOLS office (telephone: (401) 874-6825).

Finally, the possibility exists for scientists to carry out ASTEP investigations from an icebreaker in the Artic Ocean in collaboration with the NOAA Arctic Exploration Program. If enough interest and funding develop, the use of aircraft may also be made available for the deployment of instrumentation onto the ice. For further information about the NOAA Arctic Exploration Program, contact:

Dr. Kathleen Crane
Program Manager - Arctic Research
Room 101
National Oceanic and Atmospheric Administration
1335 East-West Highway,
Silver Spring, MD 20910
Telephone: (301) 713-2518 Ext. 290
E-mail: kathy.crane@noaa.gov.

2.2 Program Funding, Schedule, and Proposal Preparation

Beginning in FY 2002, $5.0M per year has been allocated to support ASTEP activities, which is immediately available to support investigations selected through this program. Assuming the submission of proposals of adequate merit, NASA anticipates selecting up to three field test campaign investigations and approximately six or more technology/science development tasks, where it is understood that the field campaigns will necessarily be much more expensive than proposals for laboratory developments. Due to the relative near-term nature of the planned Mars surface missions, priority will be given to proposed activities with documented relevance to the Mars Exploration Program (see Section 1.2 above in this program element), as well as the potential to affect missions planned for 2007-2009. Proposals may specify periods of performance of up to three years.

In order to make the best possible use of the funds available, proposers are encouraged to seek cost sharing where appropriate and to propose collective use where that is reasonable, e.g., instruments that could be made available for use by other qualified members of the astrobiology and planetary science community.

The schedule for proposals for this opportunity is:

- Notice of Intent to Propose Due Date April 26, 2002
- Proposal Due Date June 7, 2002

The evaluation criteria contained in Appendix C, Section C.2, of the *NASA Guidebook for Proposers* (see further below) shall be used to evaluate submitted proposals, where it is understood that the scientific and technical merit of any proposal for a terrestrial field test campaign will also include the following factors, of equal priority:

- A clear understanding of the campaign environment and the science to be addressed;
- Feasibility and appropriateness of the proposed instruments and the operational approach;
- The fidelity of the campaign operations and location to the analogous planetary mission; and
- The relevance and added value of the included technologies to Astrobiology science and planetary exploration.

The recommendation for funding will be based on the peer evaluation of the scientific and technical merits of each proposal, as well as the broader impacts of the activity, the relevance to NASA's Astrobiology and planetary exploration programs, and the ability to support the requested budget and logistics. NASA will manage the review process and the administration of the program with assistance and participation of NSF and NOAA as appropriate.

IMPORTANT INFORMATION

As discussed in the *Summary of Solicitation* of this NRA, the Office of Space Science (OSS) is now using a single, unified set of instructions for the submission of proposals. This material is contained in the document entitled *NASA Guidebook for Proposers Responding to NASA Research Announcement – 2001* (or *NASA Guidebook for Proposers* for short) that is accessible by opening URL http://research.hq.nasa.gov, and linking through the menu item "Helpful References, or may be directly accessed online at URL http://www.hq.nasa.gov/office/procurement/nraguidebook/. This NRA's *Summary of Solicitation* also contains instructions for electronic submission of a *Notice of Intent* (NOI) to propose and a proposal's *Cover Page/Proposal Summary* that now also includes the required *Budget Summary*, and the mailing address for the submission of a proposal. Note that when logging into NASA's proposal data base system, access to the site for the electronic submission of a *NOI* and *Cover Page* for this program element will be found under the listing "OSS – Solar System Exploration" in the menu entitled Division Specific Opportunities.

Questions concerning this ASTEP program may be directed to either of the following program personnel:

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